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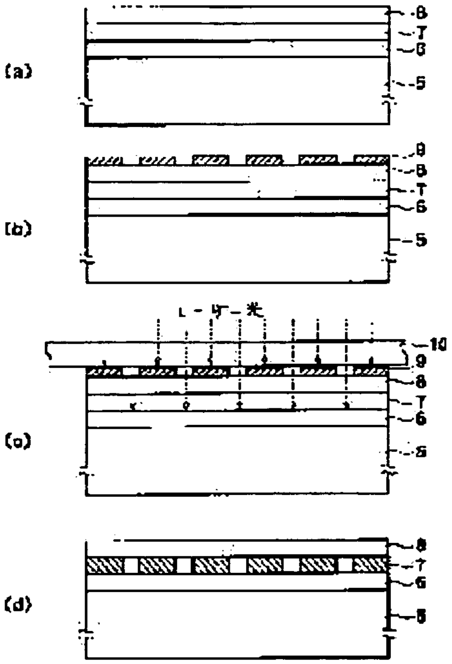
(71)Applicant : SUMITOMO ELECTRIC IND LTD
(72)Inventor : ISHIKAWA SHINJI
SAITO MASAHIDE
HATTORI TETSUYA
KANAMORI HIROO
ITO MASUMI
INAI MAKI

(54) OPTICAL WAVEGUIDE AND ITS PRODUCTION

(57)Abstract:

PURPOSE: To provide an optical waveguide having such a structure that the number of production processes can be largely decreased and characteristics can be improved, and to provide its production method.

CONSTITUTION: Three thin film layers 6, 7, 8 each comprising a glass material having same refractive index and containing at least GeO2, in the intermediate layer 7 are formed on a substrate 5. Then a specified mask pattern 9 is provided and the part where the core is to be formed in the intermediate layer 7 is irradiated with light of <260nm wavelength to produce different refractive index in the irradiated area from the area not irradiated in the thin film layers 6, 7, 8. By this method, an optical waveguide having the part where different refractive index is induced as the core and the area not irradiated in the thin film layers 6, 7, 8 as the clad is formed.



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(71)出願人　000002130
住友電気工業株式会社
大阪府大阪市中央区北浜四丁目５番33号

(72)発明者　石川　真二
神奈川県横浜市栄区田谷町１番地　住友電気工業株式会社横浜製作所内

(72)発明者　斉藤　眞秀
神奈川県横浜市栄区田谷町１番地　住友電気工業株式会社横浜製作所内

(72)発明者　服部　哲也
神奈川県横浜市栄区田谷町１番地　住友電気工業株式会社横浜製作所内

(74)代理人　弁理士　長谷川　芳樹　（外３名）

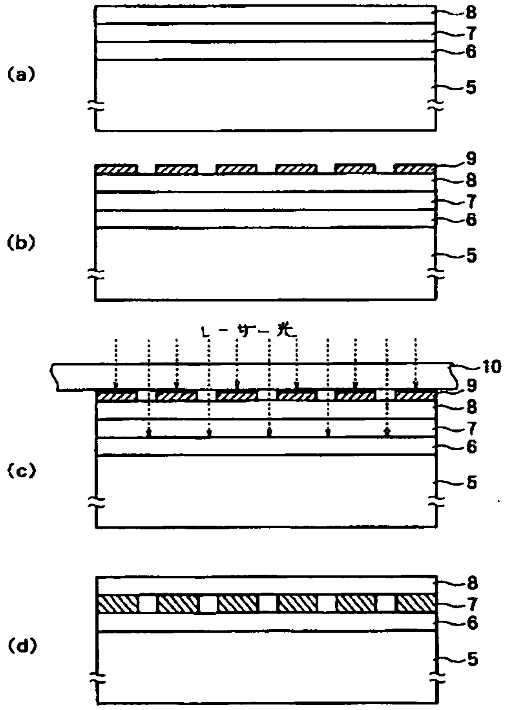
最終頁に続く

(54)【発明の名称】　光導波路及びその製造方法

(57)【要約】

【目的】　製造工程数を大幅に低減することができると共に、特性の向上を図ることができる構造を有する光導波路とその製造方法を提供する。

【構成】　夫々屈折率の等しいガラス材から成り、中間層７に少なくともGeO_2を含有する３層の薄膜層６，７，８を基板５上に積層した後、所定のマスクパターン９を設けて、中間層７中のコアを形成すべき部分に、２６０ｎｍ未満の波長の光を照射することにより、薄膜層６，７，８の光未照射部分とは異なる屈折率変化を誘起させる。これにより、屈折率変化が誘起した部分がコア、薄膜層６，７，８の光未照射部分がクラッドとなる光導波路が形成される。



【特許請求の範囲】

【請求項１】　コアを埋設したクラッドが基板上に形成されて成る光導波路の製造方法において、

夫々屈折率の等しいガラス材から成り、中間層にＧｅＯ$_2$を含有する３層の薄膜層を基板上に積層する第１の工程と、

前記中間層中のコアを形成すべき部分に、２６０ｎｍ未満の波長の光を照射することにより、前記３層の薄膜の光未照射部分とは異なる屈折率変化を誘起させる第２の工程と、を有することを特徴とする光導波路の製造方法。

【請求項２】　前記中間層には、５重量％以上のＧｅＯ$_2$と、前記薄膜層の残余の層との屈折率差を補償するだけのB_2O_3とを含有させることを特徴とする請求項１に記載の光導波路の製造方法。

【請求項３】　前記薄膜層の内の前記中間層を除く層に、B_2O_3とP_2O_5の両方又はいずれか一方を含有させることを特徴とする請求項１に記載の光導波路の製造方法。

【請求項４】　前記光には、２４８ｎｍの波長のＫｒＦエキシマレーザ光源から出射された平行光を適用することを特徴とする請求項１に記載の光導波路の製造方法。

【請求項５】　コアを埋設したクラッドが基板上に形成されて成る光導波路において、

前記コアは、少なくともＧｅＯ$_2$を含有するガラス材に２６０ｎｍ未満の波長の光を照射することにより形成され、前記クラッドは、前記コアより低屈折率のガラス材から成ることを特徴とする光導波路。

【発明の詳細な説明】

【０００１】

【産業上の利用分野】本発明は、光通信分野等に広く適用される石英系の光導波路及びその製造方法に関する。

【０００２】

【従来の技術】従来の光導波路は、図５に示すような製造プロセスによって形成されていた。即ち、シリコン基板１上に、ＦＨＤ又はＣＶＤ法により、石英ガラスから成る下部クラッド層２と、高屈折率の石英ガラス層３とを順次に積層し（図５（ａ）参照）、次に、反応エッチングにより石英ガラス層３の不要部分を除去することにより、コアとなるべき部分３ａを形成し（同図（ｂ）参照）、再びＦＨＤ又はＣＶＤ法によって、石英ガラスから成る上部クラッド層４を、上記部分３ａ及び下部クラッド層２上に積層することにより、上記部分３ａを下部クラッド層２と上部クラッド層４中に実質的に埋設していた（同図（ｃ）参照）。

【０００３】更に、各製造工程を詳述すれば、同図（ａ）の工程においては、ＦＨＤ又はＣＶＤ法により、シリコン基板１上に下部クラッド層２と石英ガラス層３とを順次に積層して焼結する。次に、同図（ｂ）の工程においては、石英ガラス層３の表面にフォトレジストを形成してパターニングを行った後に、反応エッチングにより石英ガラス層３の不要部分を除去し、そして、不要となったフォトレジストを除去する。同図（ｃ）の工程においては、再びＦＨＤ又はＣＶＤ法により、石英ガラスから成る上部クラッド層４を、上記部分３ａ及び下部クラッド層２上に積層して焼結処理する。

【０００４】このような製造方法による従来の光導波路としては、特開昭５８－１０５１１１号公報、特開平１－１８９６１４号公報、「JOURNAL OF LIGHTWAVE TECHNOLOGY,VOL.6,NO.6,JUNE 1988 pp.1003～ pp.1010」の文献に開示されている。

【０００５】

【発明が解決しようとする課題】しかし、このような従来の光導波路は、コアとなるべき部分３ａを構造的に下部クラッド２及び上部クラッド４とは分離・独立に形成した後、上部クラッド４が積層されることにより、実質的にコアとクラッドの一体化が図られた構造となっている。即ち、従来の光導波路は、かかる構造を内在するが故に、次のような問題点があった。

【０００６】まず、上記の構造を実現するために、製造工程数が多くなる問題があった。又、反応エッチングにおいて石英ガラス層３の不要部分を約１０μｍ程度の厚さで除去する必要があるので、フォトレジストによるパターニングの精度を向上させることが困難となる問題があった。更に、最終的にコアと成る上記部分３ａと上部クラッド層４との界面が平坦に成らない（例えば、数１００オングストローム程度の粗さになる）ので、散乱損失を飛躍的に低減した光導波路を実現することが困難となっていた。

【０００７】更に、コアに対して低屈折率のクラッド層４を実現する必要上、上部クラッド層４に添加物を含有させているが、この上部クラッド層４を積層する際に、添加物の拡散による上記部分３ａの変形などを招来して、設計仕様に合致した所望の特性の光導波路を製造することが困難な場合があった。

【０００８】更に又、図５（ｂ）に示すように、コアとなるべき部分３ａが、製造工程中に外部環境に晒されることとなり、環境中のダスト（塵や不純物）などが付着して、散乱損失の原因となったり、その後の加熱処理において、このダストが気泡となって散乱損失を招来する等の問題があった。

【０００９】本発明は、このような従来技術に課題に鑑みて成されたものであり、製造工程数を大幅に低減することができると共に、特性の向上を図ることができる構造を有する光導波路とその製造方法を提供することを目的とする。

【００１０】

【課題を解決するための手段】このような目的を達成するために本発明は、コアを埋設したクラッドが基板上に形成されて成る光導波路とその製造方法において、夫々

屈折率の等しいガラス材から成り、中間層にGeO_2を含有する３層の薄膜層を基板上に積層し、前記中間層中のコアを形成すべき部分に、２６０ｎｍ未満の波長の光を照射することにより、前記３層の薄膜の光未照射部分とは異なる屈折率変化を誘起させることにより、前記コアとクラッドを実現した。

【００１１】又、前記中間層には、５重量％以上のGeO_2と、前記薄膜層の残余の層との屈折率差を補償するだけのB_2O_3とを含有させておき、前記中間層中のコアを形成すべき部分に、２６０ｎｍ未満の波長の光を照射することにより、前記３層の薄膜の光未照射部分とは異なる屈折率変化を誘起させることにより、前記コアとクラッドを実現した。

【００１２】又、前記薄膜層の内の前記中間層を除く層に、B_2O_3とP_2O_5の両方又はいずれか一方を含有させておき、前記中間層中のコアを形成すべき部分に、２６０ｎｍ未満の波長の光を照射することにより、前記３層の薄膜の光未照射部分とは異なる屈折率変化を誘起させることにより、前記コアとクラッドを実現した。

【００１３】又、前記光には、２４８ｎｍの波長のＫｒＦエキシマレーザ光源から出射された平行光を適用することとした。

【００１４】

【実施例】以下、本発明による光導波路とその製造方法の一実施例を図面と共に説明する。 まず、図１に基づいてその製造方法を説明する。同図（ａ）に示すように、シリコン基板５上に、火炎体積法（ＦＨＤ法）により、下部クラッド層６と、コア形成層７と、上部クラッド層８を順次に積層する。

【００１５】ここで、下部クラッド層６と上部クラッド層８は、B_2O_3を５重量％且つP_2O_5を７重量％含有するシリコンガラスで形成し、コア形成層７は、GeO_2を１５重量％且つB_2O_3を２０重量％含有する石英ガラスで形成することにより、下部クラッド層６及び上部クラッド層８に対するコア形成層７の比屈折率差を、コア形成層７の方が約０．０２％高く成るようにした。更に、下部クラッド層６の厚さを約１５μｍ、コア形成層７の厚さを約７μｍ、上部クラッド層８の厚さを約１０μｍとした。

【００１６】尚、B_2O_3は、シリコンガラス或いは石英ガラスの屈折率を低下させるための添加剤（以下、屈折率低下剤という）であり、GeO_2とP_2O_5は、シリコンガラス或いは石英ガラスの屈折率を上昇させるための添加剤（以下、屈折率上昇剤という）である。よって、上記したように、下部クラッド層６及び上部クラッド層８に対するコア形成層７の比屈折率差を所望の値に設定するために、下部クラッド層６と上部クラッド層８に夫々所定量の屈折率低下剤B_2O_3と屈折率上昇剤P_2O_5を含有させることによって、これらの層６，８の屈折率の制御を行うと共に、コア形成層７に夫々所定量の屈折率低下剤B_2O_3と屈折率上昇剤GeO_2を含有させることによって、この層７の屈折率の制御を行っている。

【００１７】但し、かかる含有率の設定態様は選択事項であり、これに限定されるものではない。例えば、石英ガラスに５重量％以上のGeO_2を含有させたコア形成層７を予め想定しておき、下部クラッド層６と上部クラッド層８に対するコア形成層７の比屈折率差が所定の値と成るように、下部クラッド層６と上部クラッド層８及びコア形成層７に含有させる屈折率低下剤B_2O_3と屈折率上昇剤P_2O_5の含有率を適宜に補償制御するようにしてもよい。

【００１８】そして、このような補償制御を行うためには、これらの屈折率低下剤と屈折率上昇剤を全く含有しないシリコンガラスと石英ガラスを、図１（ａ）に示す下部クラッド層６及び上部クラッド層８及びコア形成層７のような３層構造に積層したとしたならば、相互に屈折率差が生じない構造を実験等により予め確認しておき、かかる構造を基準にして、屈折率低下剤と屈折率上昇剤の含有率を設定するのが好適である。

【００１９】次に、スパッタ法により、上部クラッド層８の上面に、約２０００オングストロームの厚さのシリコン膜を蒸着した後、感光性レジストを塗布して所望のコアパターンを露光し、更に、図１（ｂ）に示すように、塩素ガスによるプラズマエッチングにより、シリコン膜の内のコアパターンに対応する部分のみを除去し、残余のシリコン膜９を残存させる。ここで、例えば、最終的に形成すべきコアの内径ｒを６μｍとするために、シリコン膜９の各幅を６μｍとした。又、コアパターンを形成するためのフォトマスクとしては、例えば、図２（ａ）～（ｃ）に示すような任意のパターン形状を有するものが適用できる。図２（ａ）の例は、長さＬ＝４０ｍｍ、幅Ｗ＝５ｍｍのガラス基板に８分岐回路を実現するためのコアパターンを形成したものであり、図２（ｂ）の例は、長さＬ＝４０ｍｍ、幅Ｗ＝５ｍｍのガラス基板に２×８分岐回路を実現するためのコアパターンを形成したものであり、図２（ｃ）の例は、長さＬ＝４０ｍｍ、幅Ｗ＝５ｍｍのガラス基板に２×２分岐回路を４組実現するためのコアパターンを形成したものである。

【００２０】次に、シリコン膜９を設けたままの状態で、１００気圧、５０℃の水素雰囲気中に約１日間収容することにより、下部クラッド層６とコア形成層７及び上部クラッド層８の内の、コアパターンに対応する部分に水素ガスを拡散浸透させる。

【００２１】次に、図１（ｃ）に示すように、シリコン膜９によるコアパターンと同一縮率のコアパターンを有するマスク１０をシリコン膜９上に配置し、マスク１０の上方から波長が２４８ｎｍ且つ強度が５００ｋＪ／ｃm^2のＫｒＦエキシマレーザ光を、約２０分間平行照射

することにより、シリコン膜９の除去されている部分（コアパターンの部分）に光照射する。そして、光照射の後、不要となったシリコン膜９を除去する。

【００２２】このように、特定波長の光を照射すると、コア形成層７の内の光の照射された部分（図１（ｄ）中の斜線部分）の屈折率が、光の照射されないコア形成層７の残余の領域と下部クラッド層６及び上部クラッド層８よりも、約０．２３％上昇し、コアとクラッドの比屈折率差が０．２５％となる光導波路を最終的に実現することができる。

【００２３】尚、図３は、上記条件のＫｒＦエキシマレーザ光を照射したことにより得られたコアとクラッドの比屈折率差の実測結果を示し、同図中の○印で示す特性曲線は、コアパターンに対応する部分に上記条件で水素ガスを拡散浸透させた後に、上記条件のＫｒＦエキシマレーザ光を照射した場合の、光照射時間に対する比屈折率差の変化を示し、同図中の△印で示す特性曲線は、水素ガスを拡散浸透させることなく、上記条件のＫｒＦエキシマレーザ光を照射した場合の、光照射時間に対する比屈折率差の変化を対比して示す。同図から明らかなように、水素ガスを拡散浸透させた後に、ＫｒＦエキシマレーザ光を照射することにより、コアとなるべき部分に高屈折率の結晶欠陥を発生させることができ、図４中の実線にて示す如く、最終的にクラッド（Ｂ，Ｄの部分）よりも高屈折率のコア（Ｃの部分）を実現することができる。尚、図４中の部分Ａは基板に相当する。

【００２４】ここで、上記のエキシマレーザを用いた結果、高強度且つ２６０ｎｍ未満の単一波長光（紫外光）による照射が可能となり、コア形成層７中にコアとなるべき高屈折率の結晶欠陥を実現することができる。即ち、低圧水銀ランプや重水素ランプでは、強度が低く且つ波長幅を有するので、好適でない。

【００２５】更に、かかる製造方法により、長さ４０ｍｍの直線光導波路を製造し、その伝送損失を実測したところ、シングルモードファイバとの接続損を含んでも、最低０．０５ｄＢ、最大で０．２５ｄＢ、平均で０．１２ｄＢ程度であり、極めて伝送損失の少ない光導波路を実現することができることが確認された。

【００２６】又、図２（ａ）に示すマスクパターンによる８分岐回路を有すると共に、各分岐構造をＹ分岐型とした光導波路の伝送損失を実測したところ、その全体の伝送損失は平均で９．６５ｄＢ（回路損失９ｄＢ）で、１分岐当たりの損失は０．２ｄＢ程度であった。これは、コアの分岐形状が良好であり、放射損失が少ないことに起因する。又、この実施例の結果と従来技術との比較を行うために、図２（ａ）に示すマスクパターンを用いて従来のＦＨＤ－ＲＩＥ法の組み合わせによる、８分岐回路を有する光導波路を製造し、その光導波路の伝送損失を実測したところ、全体の伝送損失は平均で１０．５ｄＢであり、当該実施例の方が明らかに平均で０．８ｄＢの特性向上が見られた。

【００２７】又、低温下で高圧の前記の水素処理を行ったり、高温で短時間の水素処理を行うことにより、ＧｅO_2 による欠陥のプリカーサーを増加させ、これに前記の光照射を行うことにより、例えば、コアとクラッドの比屈折率差を０．１％以上にすることも可能である。

【００２８】以上に説明したように、この実施例によれば、従来技術と比較して製造工程数を大幅に低減することができ、又、反応エッチングなどによりコアとなるべき部分を予め形成しないので、コアとクラッドとの界面を容易に平坦化することができると共に不純物などの混入を未然に防止して、散乱損失の少ない光導波路を実現することができる。

【００２９】

【発明の効果】以上に説明したように本発明によれば、製造工程数を大幅に低減することができると共に、特性の向上を図ることができる構造を有する光導波路とその製造方法を提供することができる。

【図面の簡単な説明】

【図１】本発明による光導波路の構造及びその製造方法の一実施例を説明する説明図である。

【図２】光導波路のコアパターンの一例を示す説明図である。

【図３】光照射時間に対するコアとクラッドの比屈折率差の変化特性を示すグラフである。

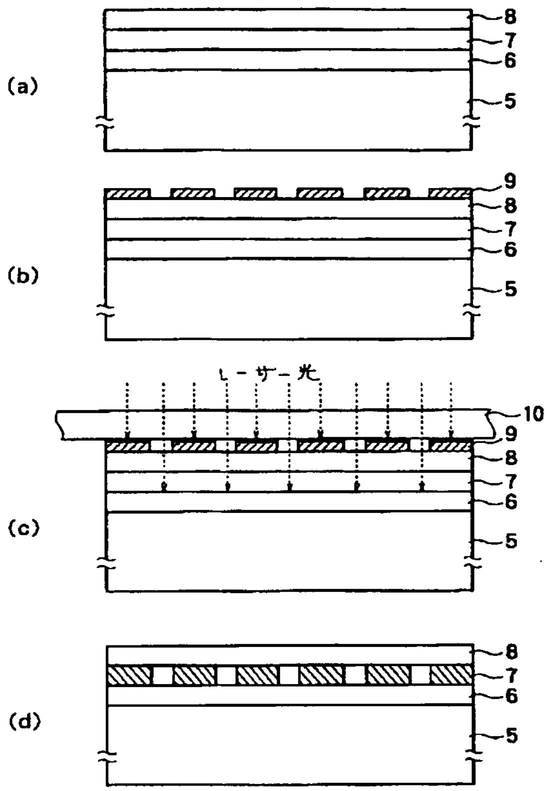
【図４】コアとクラッドの屈折率分布を説明するためのグラフである。

【図５】従来の光導波路の製造方法を説明するための説明図である。

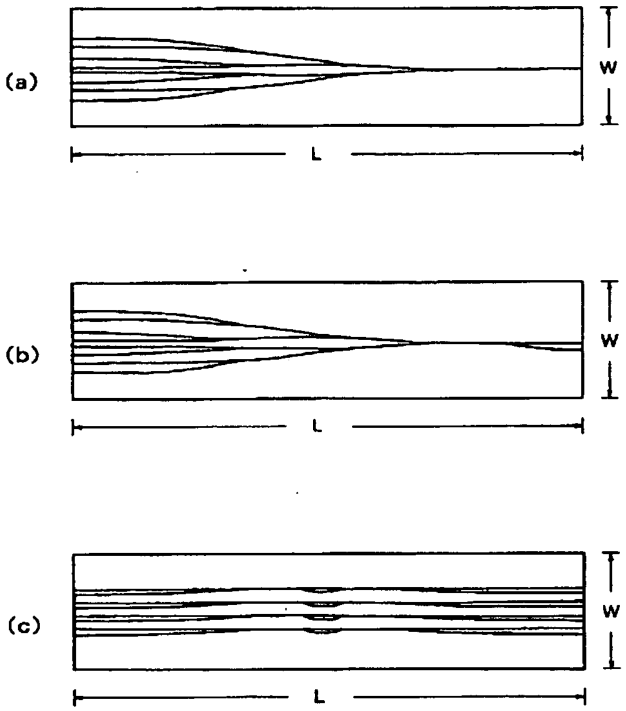
【符号の説明】

５…シリコン基板、６…下部クラッド層、７…コア形成層、８…上部クラッド層、９…シリコン層、１０…マスク。

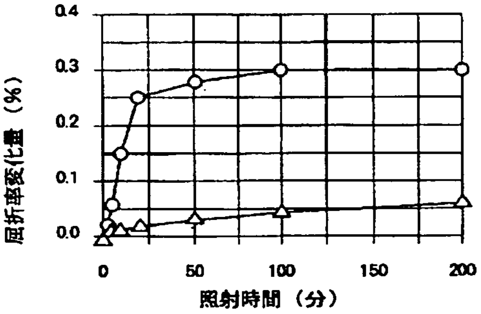
【図1】



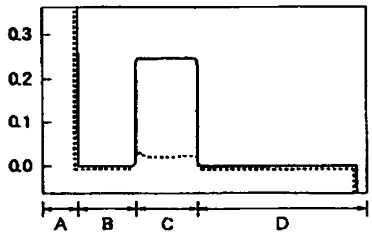
【図2】



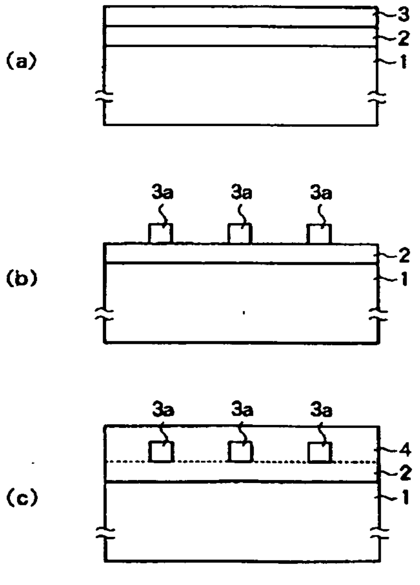
【図3】



【図4】



【図5】



フロントページの続き

(72)発明者　金森　弘雄
神奈川県横浜市栄区田谷町1番地　住友電
気工業株式会社横浜製作所内

(72)発明者　伊藤　真澄
神奈川県横浜市栄区田谷町1番地　住友電
気工業株式会社横浜製作所内

(72)発明者　稲井　麻紀
神奈川県横浜市栄区田谷町1番地　住友電
気工業株式会社横浜製作所内

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CLAIMS

[Claim(s)]
[Claim 1] In the manufacture approach of optical waveguide that the clad which laid the core underground is formed on a substrate and changes It consists of glass material with a respectively equal refractive index, and is GeO2 to an interlayer. By irradiating light with a wavelength of less than 260nm into the 1st process which carries out the laminating of the three-layer thin film layer to contain on a substrate, and the part which should form the core in said interlayer The manufacture approach of the optical waveguide characterized by having the 2nd process to which induction of the refractive-index change which is different in a part for the non-irradiated area of said thin film of three layers is carried out.
[Claim 2] In said interlayer, it is 5% of the weight or more of GeO2. Only B-2 O3 which compensates a refractive-index difference with the layer of the remainder of said thin film layer The manufacture approach of the optical waveguide according to claim 1 characterized by making it contain.
[Claim 3] To the layer except said interlayer of said thin film layers, it is B-2 O3. P2 O5 The manufacture approach of the optical waveguide according to claim 1 characterized by making both or either contain.
[Claim 4] The manufacture approach of the optical waveguide according to claim 1 characterized by applying the parallel light by which outgoing radiation was carried out from the KrF excimer laser with a wavelength of 248nm to said light.
[Claim 5] Setting to the optical waveguide of which the clad which laid the core underground is formed on a substrate, and consists, said core is GeO2 at least. It is the optical waveguide which is formed by irradiating light with a wavelength of less than 260nm at the glass material to contain, and is characterized by said clad consisting of the glass material of a low refractive index from said core.

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DETAILED DESCRIPTION

[Detailed Description of the Invention]
[0001]
[Industrial Application] This invention relates to the optical waveguide and its manufacture approach of the quartz system widely applied to the optical-communication field etc.
[0002]
[Description of the Prior Art] The conventional optical waveguide was formed of the manufacture process as shown in drawing 5 . Namely, the lower cladding layer 2 which consists of quartz glass with FHD or a CVD method on a silicon substrate 1, By carrying out the laminating of the quartz-glass layer 3 of a high refractive index one by one (referring to drawing 5 (a)), next removing the garbage of the quartz-glass layer 3 by reaction etching Partial 3a which should become a core is formed (refer to this drawing (b)). Again with FHD or a CVD method The above-mentioned partial 3a was substantially laid underground into the lower cladding layer 2 and the up cladding layer 4 by carrying out the laminating of the up cladding layer 4 which consists of quartz glass on above-mentioned partial 3a and the lower cladding layer 2 (refer to this drawing (c)).
[0003] Furthermore, if each production process is explained in full detail, in the process of this drawing (a), on a silicon substrate 1, the laminating of the lower cladding layer 2 and the quartz-glass layer 3 will be carried out one by one, and they will be sintered with FHD or a CVD method. Next, in the process of this drawing (b), after forming a photoresist in the front face of the quartz-glass layer 3 and performing patterning, reaction etching removes the garbage of the quartz-glass layer 3, and the photoresist which became unnecessary is removed. In the process of this drawing (c), again, with FHD or a CVD method, the laminating of the up cladding layer 4 which consists of quartz glass is carried out on above-mentioned partial 3a and the lower cladding layer 2, and sintering processing is carried out.
[0004] It is indicated by JP,58-105111,A, JP,1-189614,A, and the reference of "JOURNAL OF LIGHTWAVE TECHNOLOGY, VOL.6, NO.6, JUNE 1988 pp.1003- pp.1010" as conventional optical waveguide by such manufacture approach.
[0005]
[Problem(s) to be Solved by the Invention] However, as for the lower clad 2 and the up clad 4, the up clad 4 separation and after forming independently has structurally a core and the structure where unification of a clad was attained, substantially by carrying out a laminating in partial 3a from which such conventional optical waveguide should serve as a core. That is, although the conventional optical waveguide was inherent in this structure therefore, it had the following troubles.
[0006] First, in order to realize the above-mentioned structure, there was a problem more than which the number of production processes increases. Moreover, since the garbage of the quartz-glass layer 3 needed to be removed by the thickness of about 10 micrometers in reaction etching, there was a problem from which it becomes difficult to raise the precision of patterning by the photoresist. Furthermore, it was difficult to realize optical waveguide which reduced scattering loss by leaps and bounds by that (for example, for it to become about several 100A granularity) of which the interface of a core, the above-mentioned partial 3a which changes, and the up cladding layer 4 finally does not consist evenly.

[0007] Furthermore, although the up cladding layer 4 was made to contain an additive, when carrying out the laminating of this up cladding layer 4, deformation of the above-mentioned partial 3a by diffusion of an additive etc. was invited, and there was a case where it was difficult to manufacture the optical waveguide of the property of the request corresponding to a design specification on the need of realizing the cladding layer 4 of a low refractive index to a core.
[0008] Furthermore, as shown in drawing 5 (b), there was a problem of this dust serving as [in / partial 3a which should become a core will be exposed to an external environment into a production process, and the dust in an environment (dust and impurity) etc. adheres, and / in becoming the cause of scattering loss **** / subsequent heat-treatment] air bubbles, and inviting scattering loss again.
[0009] This invention aims at offering the optical waveguide which has the structure where improvement in a property can be aimed at, and its manufacture approach while it can be accomplished in view of a technical problem on such a conventional technique and can reduce the number of production processes sharply.
[0010]
[Means for Solving the Problem] In the optical waveguide of which the clad which laid the core underground is formed on a substrate, and this invention consists in order to attain such a purpose, and its manufacture approach It consists of glass material with a respectively equal refractive index, and is GeO2 to an interlayer. By carrying out the laminating of the three-layer thin film layer to contain on a substrate, and irradiating light with a wavelength of less than 260nm at the part which should form the core in said interlayer Said core and clad were realized by carrying out induction of the refractive-index change which is different in a part for the non-irradiated area of said thin film of three layers.
[0011] Moreover, in said interlayer, it is 5% of the weight or more of GeO2. Only B-2 O3 which compensates a refractive-index difference with the layer of the remainder of said thin film layer It is made to contain. Said core and clad were realized by carrying out induction of the refractive-index change which is different by irradiating light with a wavelength of less than 260nm in a part for the non-irradiated area of said thin film of three layers to the part which should form the core in said interlayer.
[0012] Moreover, it is B-2 O3 to the layer except said interlayer of said thin film layers. P2 O5 Said core and clad were realized by making both or either contain and carrying out induction of the refractive-index change which is different by irradiating light with a wavelength of less than 260nm in a part for the non-irradiated area of said thin film of three layers to the part which should form the core in said interlayer.
[0013] Moreover, we decided to apply the parallel light by which outgoing radiation was carried out from the KrF excimer laser with a wavelength of 248nm to said light.
[0014]
[Example] Hereafter, one example of the optical waveguide by this invention and its manufacture approach is explained with a drawing. First, the manufacture approach is explained based on drawing 1 . As shown in this drawing (a), the laminating of the lower cladding layer 6, the core formative layer 7, and the up cladding layer 8 is carried out one by one by the flame volume method (FHD law) on a silicon substrate 5.
[0015] Here, the lower cladding layer 6 and the up cladding layer 8 are B-2 O3. 5 % of the weight and P2 O5 Forming with the silicon glass contained 7% of the weight, the core formative layer 7 is GeO2 15 % of the weight and B-2 O3 The relative index difference of the core formative layer 7 to the lower cladding layer 6 and the up cladding layer 8 was made for the direction of the core formative layer 7 to change highly about 0.02% by forming with the quartz glass contained 20% of the weight. Furthermore, thickness of about 7 micrometers and the up cladding layer 8 was set [the thickness of the lower cladding layer 6] to about 10 micrometers for the thickness of about 15 micrometers and the core formative layer 7.
[0016] In addition, B-2 O3 It is an additive (henceforth a refractive-index fall agent) for reducing the refractive index of silicon glass or quartz glass, and is GeO2. P2 O5 It is an additive (henceforth a refractive-index rise agent) for raising the refractive index of silicon glass or quartz glass. Therefore, as described above, in order to set the relative index difference of the core formative layer 7 to the lower

cladding layer 6 and the up cladding layer 8 as a desired value the lower cladding layer 6 and the up cladding layer 8 -- respectively -- the refractive-index fall agent of the specified quantity -- B-2 O3 a refractive-index rise agent -- P2 O5 While controlling the refractive index of these layers 6 and 8 by making it contain It is refractive-index low laxative B-2 O3 of the specified quantity to the core formative layer 7, respectively. Refractive-index rise agent GeO 2 The refractive index of this layer 7 is controlled by making it contain.

[0017] However, the setting mode of this content is a selection matter, and is not limited to this. for example, quartz glass -- 5% of the weight or more of GeO2 the refractive-index fall agent which the lower cladding layer 6, the up cladding layer 8, and the core formative layer 7 are made to contain so that the relative index difference of the core formative layer 7 to the lower cladding layer 6 and the up cladding layer 8 may change with a predetermined value beforehand supposing the core formative layer 7 made to contain -- B-2 O3 a refractive-index rise agent -- P2 O5 It may be made to carry out the compensatory control of the content suitably.

[0018] and in order to perform such a compensatory control Supposing it carries out a laminating to a three-tiered structure like the lower cladding layer 6 which shows the silicon glass which does not contain these refractive-index fall agents and a refractive-index rise agent at all, and quartz glass to drawing 1 (a), the up cladding layer 8, and the core formative layer 7 The structure which a refractive-index difference does not produce is mutually checked beforehand by experiment etc., and it is suitable to set up the content of a refractive-index fall agent and a refractive-index rise agent on the basis of this structure.

[0019] Next, after vapor-depositing a silicone film with a thickness of about 2000A on the top face of the up cladding layer 8 by the spatter, a photosensitive resist is applied, a desired core pattern is exposed, only the part corresponding to the core pattern of the silicone films is removed, and the residual silicone film 9 is made to remain by plasma etching by chlorine gas further, as shown in drawing 1 (b). Here, in order to set to 6 micrometers the bore r of the core which should finally be formed, for example, each width of face of a silicone film 9 was set to 6 micrometers. Moreover, what has the pattern configuration of arbitration as shown in drawing 2 (a) - (c) as a photo mask for forming a core pattern, for example is applicable. The example of drawing 2 (a) forms the core pattern for realizing eight branch circuits to a glass substrate with a die length [of L= 40mm], and a width of face of W= 5mm. The example of drawing 2 (b) Forming the core pattern for realizing 2x8 branch circuits to a glass substrate with a die length [of L= 40mm], and a width of face of W= 5mm, the example of drawing 2 (c) forms the core pattern for realizing 4 sets of 2x dichotomy circuits to a glass substrate with a die length [of L= 40mm], and a width of face of W= 5mm.

[0020] Next, the part corresponding to the core pattern of the lower cladding layer 6, the core formative layer 7, and the up cladding layers 8 is made to carry out diffusion osmosis of the hydrogen gas in the condition [having formed the silicone film 9] by holding for about one day into 100 atmospheric pressures and a 50-degree C hydrogen ambient atmosphere.

[0021] Next, the mask 10 which has the core pattern of the same shrinking percentage as the core pattern by the silicone film 9 as shown in drawing 1 (c) is arranged on a silicone film 9, and, for wavelength, 248nm and reinforcement are 500 kJ/cm2 from the upper part of a mask 10. The optical exposure of the KrF excimer laser light is carried out by carrying out the parallel exposure during about 20 minutes at the part (part of a core pattern) from which the silicone film 9 is removed. And the silicone film 9 which became unnecessary is removed after an optical exposure.

[0022] Thus, if the light of specific wavelength is irradiated, rather than the field, the residual lower cladding layer 6, and the residual up cladding layer 8 of the core formative layer 7 by which light is not irradiated, the refractive index of the part (shadow area in drawing 1 (d)) by which the light of the core formative layers 7 was irradiated rises about 0.23%, and, finally can realize optical waveguide from which the relative index difference of a core and a clad becomes 0.25%.

[0023] In addition, the characteristic curve which drawing 3 shows the observation result of the relative index difference of a core and a clad obtained by having irradiated the KrF excimer laser light of the above-mentioned conditions, and is shown by O mark in this drawing After making the part corresponding to a core pattern carry out diffusion osmosis of the hydrogen gas on the above-mentioned conditions The characteristic curve which shows change of the relative index difference over the optical irradiation time at the time of irradiating the KrF excimer laser light of the above-mentioned conditions, and is shown by ** mark in this drawing Change of the relative index difference over the optical irradiation time at the time of irradiating the KrF excimer laser light of the above-mentioned conditions is shown by comparison, without carrying out diffusion osmosis of the hydrogen gas. After carrying out diffusion osmosis of the hydrogen gas so that clearly from this drawing, by irradiating KrF excimer laser light, the part which should serve as a core can be made to generate the crystal defect of a high refractive index, and as the continuous line in drawing 4 shows, finally the core (part of C) of a high refractive index can be realized rather than a clad (parts of B and D). In addition, the part A in drawing 4 is equivalent to a substrate.

[0024] Here, as a result of using the above-mentioned excimer laser, the crystal defect of a high refractive index which the exposure of by high intensity and less than 260nm single wavelength light (ultraviolet radiation) should be attained, and should serve as a core into the core formative layer 7 is realizable. That is, since reinforcement has wavelength width of face low in a low-pressure mercury lamp or a deuterium lamp, it is not suitable.

[0025] Furthermore, although connection loss with a single mode fiber was included when straight-line optical waveguide with a die length of 40mm was manufactured and the transmission loss was surveyed by this manufacture approach, it is about 0.12dB in 0.25dB and an average at at least 0.05dB and max, and it was checked that optical waveguide with very little transmission loss is realizable.

[0026] Moreover, while having eight branch circuits by the mask pattern shown in drawing 2 (a), when transmission loss of the optical waveguide which used each branching structure as the Y branch mold was surveyed, the transmission loss of the whole was 9.65dB (9dB of losses of circuit) on the average, and the loss per branching was about 0.2dB. This originates in that the branching configuration of a core is good and there is little radiation loss. Moreover, in order to perform the comparison with the result of this example, and the conventional technique, when the optical waveguide which has eight branch circuits by the combination of the conventional FHD-RIE method using the mask pattern shown in drawing 2 (a) was manufactured and transmission loss of that optical waveguide was surveyed, the whole transmission loss is 10.5dB on an average, and the 0.8dB improvement in a property was clearly found for the direction of the example concerned on the average.

[0027] Moreover, it is GeO2 by performing the aforementioned high-pressure hydrogen processing under low temperature, or performing short-time hydrogen processing at an elevated temperature. It is also possible to make relative index difference of a core and a clad 0.1% or more by making the precursor of the defect to depend increase and performing the aforementioned optical exposure to this.

[0028] Since the part which can reduce the number of production processes sharply as compared with the conventional technique, and should serve as a core by reaction etching etc. is not beforehand formed according to this example as explained above, while being able to carry out flattening of the interface of a core and a clad easily, mixing of an impurity etc. can be prevented beforehand, and optical waveguide with little scattering loss can be realized.

[0029]

[Effect of the Invention] As explained above, while being able to reduce the number of production processes sharply according to this invention, the optical waveguide which has the structure where improvement in a property can be aimed at, and its manufacture approach can be offered.

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TECHNICAL FIELD

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PRIOR ART

[Description of the Prior Art] The conventional optical waveguide was formed of the manufacture process as shown in drawing 5 . Namely, the lower cladding layer 2 which consists of quartz glass with FHD or a CVD method on a silicon substrate 1, By carrying out the laminating of the quartz-glass layer 3 of a high refractive index one by one (referring to drawing 5 (a)), next removing the garbage of the quartz-glass layer 3 by reaction etching Partial 3a which should become a core is formed (refer to this drawing (b)). Again with FHD or a CVD method The above-mentioned partial 3a was substantially laid underground into the lower cladding layer 2 and the up cladding layer 4 by carrying out the laminating of the up cladding layer 4 which consists of quartz glass on above-mentioned partial 3a and the lower cladding layer 2 (refer to this drawing (c)).
[0003] Furthermore, if each production process is explained in full detail, in the process of this drawing (a), on a silicon substrate 1, the laminating of the lower cladding layer 2 and the quartz-glass layer 3 will be carried out one by one, and they will be sintered with FHD or a CVD method. Next, in the process of this drawing (b), after forming a photoresist in the front face of the quartz-glass layer 3 and performing patterning, reaction etching removes the garbage of the quartz-glass layer 3, and the photoresist which became unnecessary is removed. In the process of this drawing (c), again, with FHD or a CVD method, the laminating of the up cladding layer 4 which consists of quartz glass is carried out on above-mentioned partial 3a and the lower cladding layer 2, and sintering processing is carried out.
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EFFECT OF THE INVENTION

[Effect of the Invention] As explained above, while being able to reduce the number of production processes sharply according to this invention, the optical waveguide which has the structure where improvement in a property can be aimed at, and its manufacture approach can be offered.

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TECHNICAL PROBLEM

[Problem(s) to be Solved by the Invention] However, as for the lower clad 2 and the up clad 4, the up clad 4 separation and after forming independently has structurally a core and the structure where unification of a clad was attained, substantially by carrying out a laminating in partial 3a from which such conventional optical waveguide should serve as a core. That is, although the conventional optical waveguide was inherent in this structure therefore, it had the following troubles.
[0006] First, in order to realize the above-mentioned structure, there was a problem more than which the number of production processes increases. Moreover, since the garbage of the quartz-glass layer 3 needed to be removed by the thickness of about 10 micrometers in reaction etching, there was a problem from which it becomes difficult to raise the precision of patterning by the photoresist. Furthermore, it was difficult to realize optical waveguide which reduced scattering loss by leaps and bounds by that (for example, for it to become about several 100A granularity) of which the interface of a core, the above-mentioned partial 3a which changes, and the up cladding layer 4 finally does not consist evenly.
[0007] Furthermore, although the up cladding layer 4 was made to contain an additive, when carrying out the laminating of this up cladding layer 4, deformation of the above-mentioned partial 3a by diffusion of an additive etc. was invited, and there was a case where it was difficult to manufacture the optical waveguide of the property of the request corresponding to a design specification on the need of realizing the cladding layer 4 of a low refractive index to a core.
[0008] Furthermore, as shown in drawing 5 (b), there was a problem of this dust serving as [in / partial 3a which should become a core will be exposed to an external environment into a production process, and the dust in an environment (dust and impurity) etc. adheres, and / in becoming the cause of scattering loss **** / subsequent heat-treatment] air bubbles, and inviting scattering loss again.
[0009] This invention aims at offering the optical waveguide which has the structure where improvement in a property can be aimed at, and its manufacture approach while it can be accomplished in view of a technical problem on such a conventional technique and can reduce the number of production processes sharply.

[Translation done.]

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MEANS

[Means for Solving the Problem] In the optical waveguide of which the clad which laid the core underground is formed on a substrate, and this invention consists in order to attain such a purpose, and its manufacture approach It consists of glass material with a respectively equal refractive index, and is GeO2 to an interlayer. By carrying out the laminating of the three-layer thin film layer to contain on a substrate, and irradiating light with a wavelength of less than 260nm at the part which should form the core in said interlayer Said core and clad were realized by carrying out induction of the refractive-index change which is different in a part for the non-irradiated area of said thin film of three layers.
[0011] Moreover, in said interlayer, it is 5% of the weight or more of GeO2. Only B-2 O3 which compensates a refractive-index difference with the layer of the remainder of said thin film layer It is made to contain. Said core and clad were realized by carrying out induction of the refractive-index change which is different by irradiating light with a wavelength of less than 260nm in a part for the non-irradiated area of said thin film of three layers to the part which should form the core in said interlayer.
[0012] Moreover, it is B-2 O3 to the layer except said interlayer of said thin film layers. P2 O5 Said core and clad were realized by making both or either contain and carrying out induction of the refractive-index change which is different by irradiating light with a wavelength of less than 260nm in a part for the non-irradiated area of said thin film of three layers to the part which should form the core in said interlayer.
[0013] Moreover, we decided to apply the parallel light by which outgoing radiation was carried out from the KrF excimer laser with a wavelength of 248nm to said light.

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EXAMPLE

[Example] Hereafter, one example of the optical waveguide by this invention and its manufacture approach is explained with a drawing. First, the manufacture approach is explained based on drawing 1 . As shown in this drawing (a), the laminating of the lower cladding layer 6, the core formative layer 7, and the up cladding layer 8 is carried out one by one by the flame volume method (FHD law) on a silicon substrate 5.
[0015] Here, the lower cladding layer 6 and the up cladding layer 8 are B-2 O3. 5 % of the weight and P2 O5 Forming with the silicon glass contained 7% of the weight, the core formative layer 7 is GeO2 15 % of the weight and B-2 O3 The relative index difference of the core formative layer 7 to the lower cladding layer 6 and the up cladding layer 8 was made for the direction of the core formative layer 7 to change highly about 0.02% by forming with the quartz glass contained 20% of the weight. Furthermore, thickness of about 7 micrometers and the up cladding layer 8 was set [the thickness of the lower cladding layer 6] to about 10 micrometers for the thickness of about 15 micrometers and the core formative layer 7.
[0016] In addition, B-2 O3 It is an additive (henceforth a refractive-index fall agent) for reducing the refractive index of silicon glass or quartz glass, and is GeO2. P2 O5 It is an additive (henceforth a refractive-index rise agent) for raising the refractive index of silicon glass or quartz glass. Therefore, as described above, in order to set the relative index difference of the core formative layer 7 to the lower cladding layer 6 and the up cladding layer 8 as a desired value the lower cladding layer 6 and the up cladding layer 8 -- respectively -- the refractive-index fall agent of the specified quantity -- B-2 O3 a refractive-index rise agent -- P2 O5 While controlling the refractive index of these layers 6 and 8 by making it contain It is refractive-index low laxative B-2 O3 of the specified quantity to the core formative layer 7, respectively. Refractive-index rise agent GeO 2 The refractive index of this layer 7 is controlled by making it contain.
[0017] However, the setting mode of this content is a selection matter, and is not limited to this. for example, quartz glass -- 5% of the weight or more of GeO2 the refractive-index fall agent which the lower cladding layer 6, the up cladding layer 8, and the core formative layer 7 are made to contain so that the relative index difference of the core formative layer 7 to the lower cladding layer 6 and the up cladding layer 8 may change with a predetermined value beforehand supposing the core formative layer 7 made to contain -- B-2 O3 a refractive-index rise agent -- P2 O5 It may be made to carry out the compensatory control of the content suitably.
[0018] and in order to perform such a compensatory control Supposing it carries out a laminating to a three-tiered structure like the lower cladding layer 6 which shows the silicon glass which does not contain these refractive-index fall agents and a refractive-index rise agent at all, and quartz glass to drawing 1 (a), the up cladding layer 8, and the core formative layer 7 The structure which a refractive-index difference does not produce is mutually checked beforehand by experiment etc., and it is suitable to set up the content of a refractive-index fall agent and a refractive-index rise agent on the basis of this structure.
[0019] Next, after vapor-depositing a silicone film with a thickness of about 2000A on the top face of

the up cladding layer 8 by the spatter, a photosensitive resist is applied, a desired core pattern is exposed, only the part corresponding to the core pattern of the silicone films is removed, and the residual silicone film 9 is made to remain by plasma etching by chlorine gas further, as shown in drawing 1 (b). Here, in order to set to 6 micrometers the bore r of the core which should finally be formed, for example, each width of face of a silicone film 9 was set to 6 micrometers. Moreover, what has the pattern configuration of arbitration as shown in drawing 2 (a) - (c) as a photo mask for forming a core pattern, for example is applicable. The example of drawing 2 (a) forms the core pattern for realizing eight branch circuits to a glass substrate with a die length [of L= 40mm], and a width of face of W= 5mm. The example of drawing 2 (b) Forming the core pattern for realizing 2x8 branch circuits to a glass substrate with a die length [of L= 40mm], and a width of face of W= 5mm, the example of drawing 2 (c) forms the core pattern for realizing 4 sets of 2x dichotomy circuits to a glass substrate with a die length [of L= 40mm], and a width of face of W= 5mm.

[0020] Next, the part corresponding to the core pattern of the lower cladding layer 6, the core formative layer 7, and the up cladding layers 8 is made to carry out diffusion osmosis of the hydrogen gas in the condition [having formed the silicone film 9] by holding for about one day into 100 atmospheric pressures and a 50-degree C hydrogen ambient atmosphere.

[0021] Next, the mask 10 which has the core pattern of the same shrinking percentage as the core pattern by the silicone film 9 as shown in drawing 1 (c) is arranged on a silicone film 9, and, for wavelength, 248nm and reinforcement are 500 kJ/cm2 from the upper part of a mask 10. The optical exposure of the KrF excimer laser light is carried out by carrying out the parallel exposure during about 20 minutes at the part (part of a core pattern) from which the silicone film 9 is removed. And the silicone film 9 which became unnecessary is removed after an optical exposure.

[0022] Thus, if the light of specific wavelength is irradiated, rather than the field, the residual lower cladding layer 6, and the residual up cladding layer 8 of the core formative layer 7 by which light is not irradiated, the refractive index of the part (shadow area in drawing 1 (d)) by which the light of the core formative layers 7 was irradiated rises about 0.23%, and, finally can realize optical waveguide from which the relative index difference of a core and a clad becomes 0.25%.

[0023] In addition, the characteristic curve which drawing 3 shows the observation result of the relative index difference of a core and a clad obtained by having irradiated the KrF excimer laser light of the above-mentioned conditions, and is shown by O mark in this drawing After making the part corresponding to a core pattern carry out diffusion osmosis of the hydrogen gas on the above-mentioned conditions The characteristic curve which shows change of the relative index difference over the optical irradiation time at the time of irradiating the KrF excimer laser light of the above-mentioned conditions, and is shown by ** mark in this drawing Change of the relative index difference over the optical irradiation time at the time of irradiating the KrF excimer laser light of the above-mentioned conditions is shown by comparison, without carrying out diffusion osmosis of the hydrogen gas. After carrying out diffusion osmosis of the hydrogen gas so that clearly from this drawing, by irradiating KrF excimer laser light, the part which should serve as a core can be made to generate the crystal defect of a high refractive index, and as the continuous line in drawing 4 shows, finally the core (part of C) of a high refractive index can be realized rather than a clad (parts of B and D). In addition, the part A in drawing 4 is equivalent to a substrate.

[0024] Here, as a result of using the above-mentioned excimer laser, the crystal defect of a high refractive index which the exposure of by high intensity and less than 260nm single wavelength light (ultraviolet radiation) should be attained, and should serve as a core into the core formative layer 7 is realizable. That is, since reinforcement has wavelength width of face low in a low-pressure mercury lamp or a deuterium lamp, it is not suitable.

[0025] Furthermore, although connection loss with a single mode fiber was included when straight-line optical waveguide with a die length of 40mm was manufactured and the transmission loss was surveyed by this manufacture approach, it is about 0.12dB in 0.25dB and an average at at least 0.05dB and max, and it was checked that optical waveguide with very little transmission loss is realizable.

[0026] Moreover, while having eight branch circuits by the mask pattern shown in drawing 2 (a), when

transmission loss of the optical waveguide which used each branching structure as the Y branch mold was surveyed, the transmission loss of the whole was 9.65dB (9dB of losses of circuit) on the average, and the loss per branching was about 0.2dB. This originates in that the branching configuration of a core is good and there is little radiation loss. Moreover, in order to perform the comparison with the result of this example, and the conventional technique, when the optical waveguide which has eight branch circuits by the combination of the conventional FHD-RIE method using the mask pattern shown in drawing 2 (a) was manufactured and transmission loss of that optical waveguide was surveyed, the whole transmission loss is 10.5dB on an average, and the 0.8dB improvement in a property was clearly found for the direction of the example concerned on the average.
[0027] Moreover, it is GeO2 by performing the aforementioned high-pressure hydrogen processing under low temperature, or performing short-time hydrogen processing at an elevated temperature. It is also possible to make relative index difference of a core and a clad 0.1% or more by making the precursor of the defect to depend increase and performing the aforementioned optical exposure to this.
[0028] Since the part which can reduce the number of production processes sharply as compared with the conventional technique, and should serve as a core by reaction etching etc. is not beforehand formed according to this example as explained above, while being able to carry out flattening of the interface of a core and a clad easily, mixing of an impurity etc. can be prevented beforehand, and optical waveguide with little scattering loss can be realized.

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DESCRIPTION OF DRAWINGS

[Brief Description of the Drawings]
[Drawing 1] It is an explanatory view explaining the structure of the optical waveguide by this invention, and one example of the manufacture approach.
[Drawing 2] It is the explanatory view showing an example of the core pattern of optical waveguide.
[Drawing 3] It is the graph which shows the change property of the relative index difference of a core and a clad over optical irradiation time.
[Drawing 4] It is a graph for explaining refractive-index distribution of a core and a clad.
[Drawing 5] It is an explanatory view for explaining the manufacture approach of the conventional optical waveguide.
[Description of Notations]
5 [-- An up cladding layer, 9 / -- A silicon layer, 10 / -- Mask.] -- A silicon substrate, 6 -- A lower cladding layer, 7 -- The core formative layer, 8

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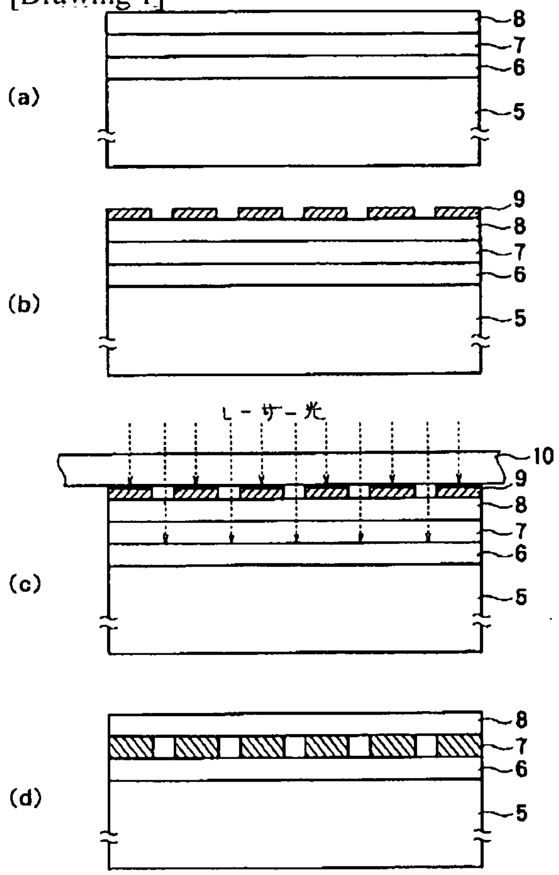
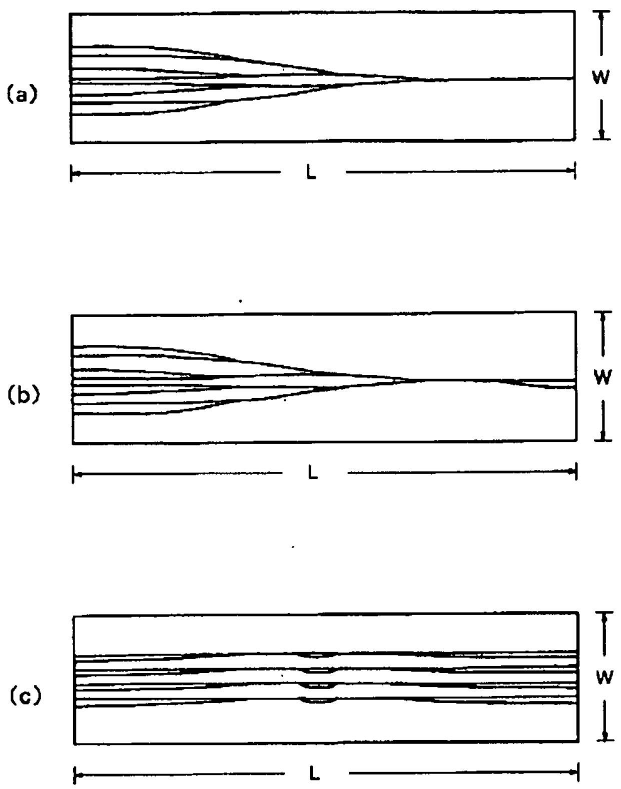
DRAWINGS

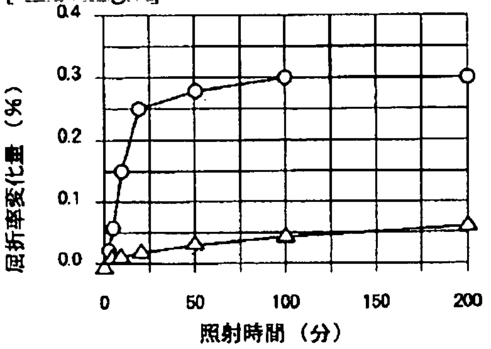
[Drawing 1]



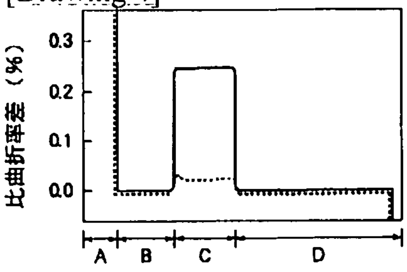
[Drawing 2]



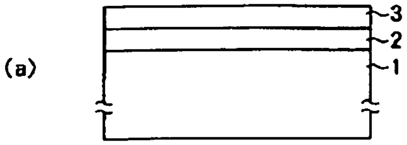
[Drawing 3]

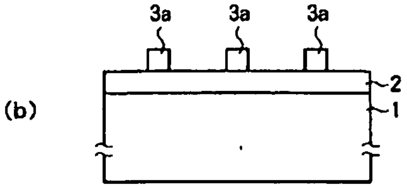


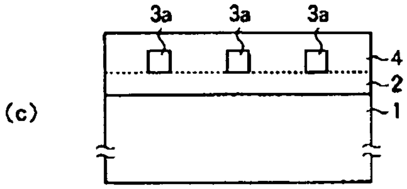
[Drawing 4]



[Drawing 5]







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